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GENERAL DYNAMICS | CONVAIR

Report No. 8926-150

Material - Aluminum - 2024-T3, 2024-T4, 7178-T6

Effect of Heating Aluminum Alloy Wing Structure To 325°F on the Mechanical Properties of its Component Materials

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Effect of Heating Aluminum Alloy Wing Structure
To 325°F on the Mechanical Properties of its
Component Materials

Abstract:

The Convair Model 22 subsonic jet transport airplane wing is subjected to a heating cycle which consists of heating from room temperature to 325°F in 3 hours, holding at 325°F for one hour and cooling to room temperature from 325°F in 4 hours. Such a heating cycle is representative of the heating encountered in an initial Mach 2 plus supersonic flight. This heating, representing an initial cycle caused (1) a reduction of 15.3 per cent of yield strength in clad 2024-T3 aluminum alloy sheet; (2) a 5.4 per cent reduction in the yield strength of 2024-T4 extrusion; (3) up to 6 per cent reduction in the yield strength of clad 7178-T6 sheet; and a 4.1 reduction in the yield strength of 7178-T6 extrusion. The ultimate strength and elongation of the 2024 alloys were slightly affected by the heating; but the ultimate strengths and elongations of the 7178 alloys underwent changes indicative of slight overaging.

Reference: Bergstedt, P. W., Turner, H. C., Sutherland, W. M., "Scotchweld - Cure Temperature Effects on the Mechanical Properties of Aluminum Alloys," General Dynamics/Convair Report MP 59-097, San Diego, California, 7 July 1959. (Reference attached).

ACCESS NO.

Title: MATERIAL - ALUMINUM - 7075-T6. EFFECT OF STRETCH STRAIGHTENING ON MECHANICAL PROPERTIES.

Authors: Bergstedt, P. W., Turner, H. C., Sutherland, W. M.

Report No.: 8926-152 Date: 16 November 1959

Contract: R.E.A. 8010

Contractor: General Dynamics/Convair

ABSTRACT: Stretching 1" x 1-1/4" x 60" extruded 7075 aluminum alloy bars in the as quenched condition 0.78, 1.74, 1.94, and 2.65 per cent reduced the distortion resulting from machining 82, 78, 86 and 82 per cent, respectively, in comparison with the distortion resulting from machining an "un-stretched" bar. The mechanical properties resulting from stretching and then aging to produce the 7075-T651 condition were:

Treatment*	F_{ty} ksi	F_{tu} ksi	Elong. % in 2"	F_{cy} ksi
No stretch	87.1	95.8	11.0	88.7
0.78% stretch	82.9	90.3	11.0	83.8
1.74% stretch	82.5	90.4	10.7	82.8
1.94% stretch	79.8	87.5	11.0	80.2
2.65% stretch	79.8	87.4	10.5	82.4

* 870°F., 95 minutes, water quench, stretch, 250°F., 24 hours.

6 pages, 2 tables, 1 figure

STRUCTURES & MATERIALS LABORATORIES

CONVAIR

A DIVISION OF GENERAL DYNAMICS CORPORATION

SAN DIEGO

REPORT MP-59-097

DATE 7 July 1959

MODEL 22

TITLE

REPORT NO. MP-59-097

SCOTCHWELD-CURE TEMPERATURE EFFECTS ON THE MECHANICAL PROPERTIES OF ALUMINUM ALLOYS

MODEL 22

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Report No. MP-59-097
Scotchweld-Cure Temperature
Effects on the Mechanical
Properties of Aluminum Alloys

INTRODUCTION

Considerable data have been accumulated concerning the effect of heat-exposure treatments upon the mechanical properties of structural aluminum alloys. During the course of the previous work, heat-exposures were chosen which were certain to equal or surpass the severity of the Scotchweld-cure treatment. The work described in this report consisted of a study of the effect of the actual Scotchweld-cure treatment upon the mechanical properties of a few selected aluminum alloy materials.

OBJECT

To determine the effect of the Scotchweld-cure treatment upon the room temperature tensile properties of:

Clad 2024-T3 sheet and plate; 2024-T4 extrusions;
Clad 7178-T6 sheet and plate; 7178-T6 extrusions.

CONCLUSIONS

The Scotchweld exposure treatment caused definite changes in the tensile properties of the test materials. The high points of these variations are listed below.

1. By causing partial relief of cold work, the Scotchweld exposure lowered the yield strength of the clad 2024-T3 materials by as much as 15.3 per cent. However, ultimate tensile strength and elongation of this material was only slightly affected.

2. Maximum yield strength reduction of the 2024-T4 extruded material was 5.4 per cent. Ultimate strength of this material was least affected of all the test materials, and elongation was increased for all gauges.

3. The tendency of the 7178-T6 materials to over-age caused yield strength reductions of up to 6 per cent in the clad stock and 4.8 per cent in the extrusions. These materials exhibited the highest losses in ultimate strength, up to 4.1 per cent for both forms. Elongation reductions were also clearly observed in these materials, but the losses did not appear excessive for this particular type of property.

TEST MATERIALS

Four materials were subjected to test:
Clad 2024-T3 sheet and plate
2024-T4 extrusions
Clad 7178-T6 sheet and plate
7178-T6 extrusions.

TEST MATERIALS (Continued)

Seven gauges, 0.080, 0.100, 0.125, 0.150, 0.190, 0.250, and 0.312, were sampled of each material. (Two gauges, 0.100 and 0.250, of the clad 7178-T6 material were not available.)

TEST SPECIMEN

A standard flat tensile specimen was used throughout the test. This type of sample has a 0.75" shoulder suitable for jaw-grips and a 0.5"x2.25" reduced test-section. The specimens were prepared in accordance with Federal Test Method Standard 151.

PROCEDURE

The work described herein was confined to tension testing, and a longitudinal sampling plan was employed for all of the materials. Six samples were required from each material -- three controls and three samples for exposure to the Scotchweld-cure cycle.

The 1"x9" coupons were cut side-by-side from the sheet and plate stock and end-to-end from pre-selected legs of the extrusions. The coupons were numbered consecutively in every instance. Odd-numbered samples were used for control tests, and even-numbered specimens were exposed to the Scotchweld-cure treatment.

Small holes were drilled in one shoulder of each of the latter specimens, and, using suitable spacers, the samples were strung on aluminum wire. The specimens (in a fully-machined condition) were then suspended within a Model 880 wing being readied for the Scotchweld cure.

Two exposure-runs were performed. The first was for the clad 2024-T3 sheet and plate. (Ref: Test Request MP-58-401) The second run accomplished the exposure of the other three test materials. During the first run two thermocouples were used; one was attached to one of the 0.080" samples, and the second measured the temperature of one of the 0.312" specimens. Since variations between the temperature-records from the two thermocouples were very slight, only one thermocouple was used during the second run. The two time-temperature records were copied for inclusion in this report (see Fig. 1).

The tensile tests were performed in a 60,000 lb. Tinius Olsen Universal Testing Machine. Standard practice was followed for all testing.

RESULTS AND DISCUSSION

The tensile test data are recorded in Tables I through IV. The changes in tensile properties attributable to the Scotchweld-cure exposure are also shown in the tables. To provide a means for rapid appraisal of the Scotchweld-cure effects, the average tensile property changes were converted to percentages (based upon as-received results) and re-tabulated in Table V.

FIG. 1. TEMPERATURE VS. TIME — SCOTCHWELD CURE TREATMENT — TENSILE SPECIMENS EXPOSED TO ACTUAL CYCLE WITH WING

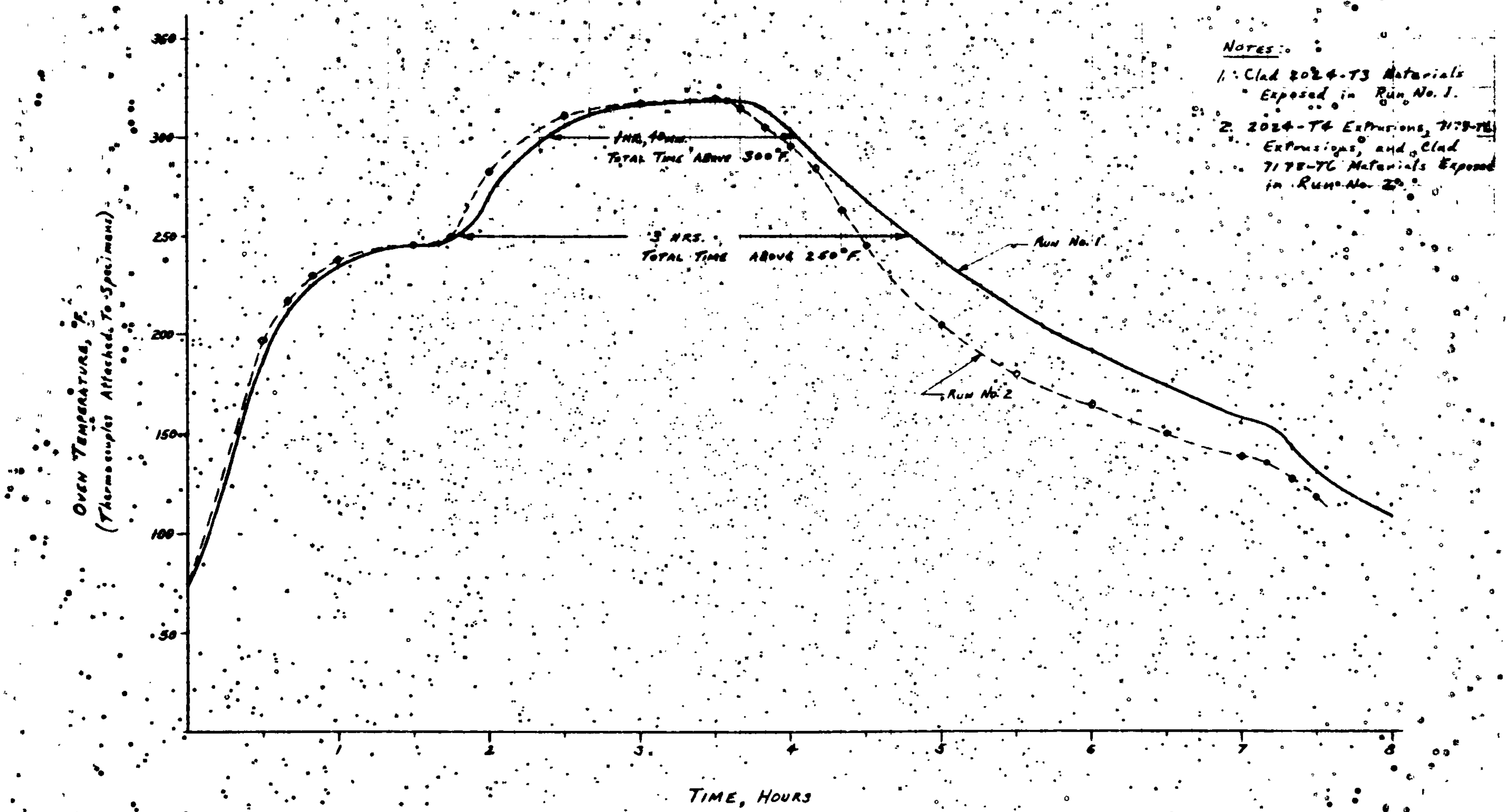

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TABLE I. EFFECT OF SCOTCHWELDING UPON THE TENSILE PROPERTIES OF CLAD 7178-T6 SHEET AND PLATE

TEST MATERIAL			AS REC'D PROPERTIES				POST-SCOTCHWELD PROPERTIES				APPARENT CHANGE IN PROPERTIES DUE TO SCOTCHWELDING (BASED UPON AVERAGE RESULTS)		
ALLOY & CONDITION	NOMINAL THICKNESS		F_{ty}, KSI 0.2% OFFSET	F_{tu}, KSI	% ELONG. 2" GAGE		F_{ty}, KSI 0.2% OFFSET	F_{tu}, KSI	% ELONG. 2" GAGE		YIELD, KSI	ULTIMATE, KSI	% ELONG.
CLAD 7178-T6 SHEET	0.080"		75.8	82.7	14.0		73.2	79.2	10.5				
			76.0	82.6	12.0		73.7	79.3	11.0				
			75.5	81.9	11.0		73.7	79.3	11.0				
		AVG:	75.8	82.0	12.3	AVG:	73.5	79.3	10.8		-2.3	-2.7	-1.5
	0.125"		78.8	85.0	12.0		75.6	81.8	10.5				
			77.9	84.3	13.0		74.8	81.5	10.5				
			78.2	83.8	12.0		74.9	81.1	11.0				
		AVG:	78.3	84.4	12.3	AVG:	75.1	81.5	10.7		-3.2	-2.9	-1.6
	0.160"		81.9	86.6	12.0		76.1	82.9	12.0				
			80.5	85.6	11.0		76.4	82.6	12.0				
			80.9	86.0	11.0		76.2	82.4	10.5				
		AVG:	81.1	86.1	11.3	AVG:	76.2	82.6	11.5		-4.9	-3.5	+0.2
CLAD 7178-T6 PLATE	0.090"		79.9	84.9	13.0		75.1	81.2	10.0				
			79.3	84.8	12.0		75.8	81.7	12.0				
			79.6	84.7	12.0		75.4	81.4	12.5				
		AVG:	79.6	84.6	12.3	AVG:	75.4	81.4	11.5		-4.2	-3.2	-0.8
	0.312"		79.5	84.1	14.0		75.0	80.8	11.5				
			78.7	83.1	13.0		74.2	79.9	12.0				
			77.7	82.3	13.0		75.3	81.0	12.0				
		AVG:	78.6	83.2	13.3	AVG:	74.8	80.6	11.8		-3.8	-2.6	-1.5

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TABLE III. EFFECT OF SCOTCHWELDING UPON THE TENSILE PROPERTIES [illegible]

Test Material: Alloy & Condition	Test Material: Nominal Thickness		As Rec'd Properties: Fty, KSI 0.2% Offset	As Rec'd Properties: Ftu, KSI	As Rec'd Properties: % Elong. 2" Gage		Post Scotchweld Properties: Fty, KSI 0.2% Offset	Post Scotchweld Properties: Ftu, KSI	Post Scotchweld Properties: % Elong. 2" Gage	Apparent Change in Properties due to Scotchwelding: Yield, KSI	Ultimate, KSI	% Elong. (Based upon Averages [illegible])
[illegible]	0.080"		51.9	64.7	14.0		49.7	64.4	19.0			
			52.7	65.0	16.5		49.5	64.1	20.0			
			52.4	64.1	16.0		49.1	64.2	18.0			
		AVG:	52.2	64.6	15.5	AVG:	49.4	64.2	19.0	- 2.8	- 0.4	+ 3.5
	0.100		52.6	65.6	18.0		50.5	65.2	19.0			
			52.5	66.1	18.5		50.4	64.5	18.0			
			52.7	66.3	17.5		50.6	64.7	19.5			
		AVG:	52.6	66.0	18.0	AVG:	50.5	64.8	18.8	- 2.1	- 1.2	+ 0.8
	0.125"		48.5	62.7	20.0		45.7	61.4	21.0			
			48.1	62.4	18.0		46.2	62.1	22.0			
			47.5	62.1	19.5		45.9	61.3	20.0			
		AVG:	48.0	62.4	19.2	AVG:	45.9	61.6	21.0	- 2.1	- 0.8	+ 1.8
	0.150"		48.1	62.0	18.0		45.8	61.1	22.5			
			48.3	63.0	20.5		46.0	60.8	20.0			
			48.6	62.5	20.0		46.5	61.9	22.0			
		AVG:	48.3	62.2	19.5	AVG:	46.1	61.3	21.5	- 2.2	- 0.9	+ 2.0
	0.190"		53.0	67.6	17.0		50.1	66.6	16.5			
			53.1	67.1	17.5		51.2	66.3	19.5			
			53.1	67.4	17.0		51.7	66.1	16.5			
		AVG:	53.1	67.2	17.2	AVG:	51.0	66.3	17.5	- 2.1	- 0.9	+ 0.3
	0.250"		56.4	73.5	14.5		54.7	72.7	18.5			
			56.8	73.3	15.0		54.7	73.1	15.5			
			57.0	74.4	14.0		54.6	73.1	16.5			
		AVG:	56.7	73.7	14.5	AVG:	54.7	73.0	16.8	- 2.0	- 0.7	+ 2.3
	0.312"		57.5	75.1	15.5		56.1	74.5	16.5			
			57.5	75.1	15.0		56.0	74.8	17.0			
			57.9	75.5	15.0		55.4	74.1	16.0			
		AVG:	57.6	75.2	15.2	AVG:	55.8	74.5	16.5	- 1.8	- 0.7	+ 1.3

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TABLE [illegible] EFFECT OF SCOTCHWELDING ON THE TENSILE PROPERTIES OF 7178-T6 EXTRUSIONS

TEST MATERIAL: ALLOY & CONDITION	NOMINAL THICKNESS		AS REC'D PROPERTIES: F_{ty}, KSI 0.2% OFFSET	F_{tu}, KSI	% ELONG. 2" GAGE		POST-SCOTCHWELD PROPERTIES: F_{ty}, KSI 0.2% OFFSET	F_{tu}, KSI	% ELONG. 2" GAGE	APPARENT CHANGE IN PROPERTIES DUE TO SCOTCHWELDING (BASED UPON AVERAGE RESULTS): YIELD, KSI	ULTIMATE, KSI	% ELONG.
7178-T6 [illegible]	0.080"		85.0	91.8	10.0		82.2	88.9	10.5			
			84.8	91.7	10.0		79.5	87.2	8.0			
			83.6	90.7	11.0		82.3	89.1	10.0			
		AVG:	84.5	91.4	10.3	AVG:	81.3	88.3	9.5	− 3.2	− 3.1	− 0.8
	0.100"		88.3	95.5	11.0		86.6	93.1	10.0			
			87.8	95.0	10.0		87.6	94.0	10.5			
			89.3	96.2	11.5		87.0	93.1	11.0			
		AVG:	88.5	95.6	10.8	AVG:	87.1	93.4	10.5	− 1.4	− 2.2	− 0.3
	0.125"		91.5	97.3	11.0		86.6	93.3	10.0			
			90.7	97.3	10.5		86.3	93.3	10.0			
			91.5	97.6	11.0		87.4	93.6	10.0			
		AVG:	91.2	97.4	10.8	AVG:	86.8	93.4	10.0	− 4.4	− 4.0	− 0.8
	0.150"		90.6	96.9	9.5		87.8	94.0	10.0			
			89.6	96.5	10.5		85.8	93.4	10.0			
			88.2	95.1	10.0		86.0	92.9	10.5			
		AVG:	89.5	96.2	10.0	AVG:	86.5	93.4	10.2	− 3.0	− 2.8	+ 0.2
	0.190"		95.6	101.8	11.0		90.7	97.5	9.0			
			95.3	101.0	10.5		92.6	98.2	10.0			
			96.7	102.5	10.5		93.4	98.4	10.0			
		AVG:	95.9	101.8	10.7	AVG:	92.2	98.0	9.7	− 3.7	− 3.8	− 1.0
	0.250"		88.7	94.8	11.0		84.3	91.2	10.5			
			90.2	95.9	11.0		86.8	92.5	9.5			
			90.7	95.8	11.5		86.6	92.5	10.5			
		AVG:	[illegible]	95.5	11.2	AVG:	85.9	92.1	10.2	− 4.0	− 3.4	− 1.0
	0.312"		86.6	94.0	10.0		86.8	94.2	12.0			
			88.5	95.0	12.0		86.1	93.4	11.5			
			87.4	94.5	11.0		82.0	91.4	11.0			
		AVG:	87.5	94.9	11.0	AVG:	85.0	93.0	11.5	− 2.5	− 1.9	+ 0.5

TABLE IV. EFFECT OF SCOTCHWELDING UPON THE PROPERTIES OF CLAD 2024 SHEET AND PLATE

TEST MATERIAL			AS REC'D PROPERTIES				POST-SCOTCHWELD PROPERTIES			APPARENT CHANGE IN PROPERTIES DUE TO SCOTCHWELDING (BASED UPON AVERAGE RESULTS)		
ALLOY & CONDITION	NOMINAL THICKNESS		F_{ty}, KSI 0.2% OFFSET	F_{tu}, KSI	% ELONG 2" GAGE		F_{ty}, KSI 0.2% OFFSET	F_{tu}, KSI	% ELONG 2" GAGE	YIELD, KSI	ULTIMATE, KSI	% ELONG
CLAD	0.080"		51.9	70.0	21.5		47.9	67.5	20.5			
2024-T3			51.9	69.9	23.0		47.6	67.4	22.0			
SHEET			51.9	70.0	19.5		48.0	67.3	20.0			
		AVG:	51.9	70.0	21.3	AVG:	47.8	67.4	20.8	- 4.1	- 2.6	- 0.5
	0.100"		52.3	69.1	20.5		48.9	68.3	19.0			
			52.3	69.0	20.0		48.7	68.4	19.0			
			51.6	69.0	20.0		48.8	67.7	21.0			
		AVG:	52.1	69.0	20.2	AVG:	48.8	68.1	19.7	- 3.3	- 0.9	- 0.5
	0.125"		49.1	67.7	20.0		47.0	67.1	19.0			
			49.2	67.7	21.0		45.9	66.9	19.5			
			49.2	67.5	22.0		46.2	67.1	20.0			
		AVG:	49.2	67.6	21.0	AVG:	46.4	67.0	19.5	- 2.8	- 0.6	- 1.5
	0.160"		52.6	68.7	18.0		50.0	67.1	18.0			
			52.6	68.7	18.5		48.7	67.0	20.0			
			52.8	68.5	19.5		49.3	66.7	18.5			
		AVG:	52.7	68.6	18.7	AVG:	49.3	66.9	18.8	- 3.4	- 1.7	+ 0.1
CLAD	0.190"		50.6	70.3	21.5		45.1	68.0	22.0			
2024-T3			49.2	70.0	20.5		45.8	68.0	19.5			
PLATE			49.3	70.1	20.0		43.8	67.5	20.5			
		AVG:	49.7	70.1	20.7	AVG:	44.9	67.8	20.7	- 4.8	- 2.3	0.0
CLAD	0.250"		52.2	65.0	19.5		47.2	63.2	20.0			
2024-T4			52.0	65.0	20.0		48.2	63.0	19.0			
PLATE			52.5	65.4	19.5		47.1	63.2	22.0			
		AVG:	52.2	65.1	19.7	AVG:	47.5	63.1	20.3	- 4.7	- 2.0	+ 0.6
	0.312"		64.0	69.4	20.0		54.2	68.4	18.5			
			63.7	69.2	19.5		54.2	68.2	19.5			
			63.9	69.4	18.0		53.9	68.1	19.5			
		AVG:	63.9	69.3	19.2	AVG:	54.1	68.2	19.2	- 9.8	- 1.1	0.0

TABLE V. APPARENT EFFECT OF SCOTCHWELD-EXPOSURE UPON THE TENSILE PROPERTIES OF FOUR ALUMINUM-ALLOY MATERIALS.

Mechanical Property Under Consideration	Material Description[1] Alloy, Condition, and Form	Percent[2] Change in Tensile Property After Scotchweld-Exposure							
		Nominal Thickness of Material, In.							Avg.
		0.080	0.100	0.125	0.150–0.160	0.190	0.250	0.312	
Tensile Yield Strength	Clad 2024-T3 Sheet & Plate	−7.9	−6.3	−5.7	−6.5	−9.7	−9.0	−15.3	−8.6
	Clad 7178-T6 Sheet & Plate	−3.0	—	−4.1	−6.0	−5.3	—	−4.8	−4.6
	2024-T4 Extrusion	−5.4	−4.0	−4.4	−4.6	−4.0	−3.5	−3.1	−4.1
	7178-T6 Extrusion	−3.8	−1.6	−4.8	−3.4	−3.9	−4.5	−2.9	−3.6
Ultimate Tensile Strength	Clad 7178-T6 Sheet & Plate	−3.3	—	−3.4	−4.1	−3.8	—	−3.1	−3.5
	7178-T6 Extrusion	−3.4	−2.3	−4.1	−2.9	−3.7	−3.6	−2.0	−3.1
	Clad 2024-T3 Sheet & Plate	−3.7	−1.3	−0.9	−2.5	−3.3	−3.1	−1.6	−2.3
	2024-T4 Extrusion	−0.6	−1.8	−1.3	−1.4	−1.3	−0.9	−0.9	−1.2
Elongation	Clad 7178-T6 Sheet & Plate	−12.2	—	−13.0	+1.8	−6.5	—	−11.3	−8.2
	7178-T6 Extrusion	−7.8	−2.8	−7.4	+2.0	−9.4	−8.9	+4.5	−4.3
	Clad 2024-T3 Sheet & Plate	−2.3	−2.5	−7.1	+0.5	0	+3.0	0	−1.2
	2024-T4 Extrusion	+22.6	+4.4	+9.4	+10.3	+1.7	+15.9	+8.6	+10.4

[1] For each tensile property, the materials are listed in order of decreasing deleterious effects.

[2] These percentages were calculated from the average values shown in Tables I – IV.